FROM WORKING LIST TO ONLINE FLORA OF ALL KNOWN PLANTS—LOOKING FORWARD WITH HINDSIGHT[1]

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ABSTRACT

The aim of this paper is to identify factors that might assist implementation of Target 1 for the Global Strategy for Plant Conservation (GSPC) for 2020: "an online flora of all known plants." This is done by considering progress in large regional floras to date and production of The Plant List online, in conjunction with lessons learned from the first 10 years of GSPC implementation. If the online flora is to support GSPC implementation, then it has to be able to support conservation and sustainable-use projects at national and local levels in addition to linking to information concerning global plant diversity. This will require strong partnerships and collaborations across the botanical community. Measurement of progress will help identify gaps and direct efforts, and indicators for measuring progress are suggested.

Key words: Flora, Global Strategy for Plant Conservation (GSPC), The Plant List, Targets.

The Global Strategy for Plant Conservation (GSPC) was adopted by the Conference of Parties (COP) of the Convention on Biological Diversity (CBD) in April 2002 (CBD, 2002). Target 1 ("a widely accessible working list of known plants species as a step towards a World Flora") was globally achieved on schedule on 29 December 2010 with the online launching of The Plant List (<www.theplantlist.org>). Ten years on from the original setting of Target 1, what lessons have we learned that can guide our responses and the implementation of the new Target 1 for 2020? As agreed at the 10th COP of the CBD in Nagoya, Japan, the revised Target 1 is "an online flora of all known plants" by 2020 (CBD, 2010a; <http://www.cbd.int/decision/cop/?id=12283>).

THE PLANT LIST

The Plant List was created to meet the 2010 Target 1 of the GSPC. This was a broad collaboration, coordinated by the Royal Botanic Gardens, Kew, and the Missouri Botanical Garden (MO), involving diverse partnerships. These extended from global data resources such as The International Compositae Alliance, which produced the Global Compositae Checklist (<http://compositae.landcareresearch.co.nz/>), the International Legume Database and Information Service (<http://www.ildis.org/>), to the International Plant Names Index (IPNI; <www.ipni.org>). Regional resources included various regional checklists held within the Tropicos database, including the African Plant Database (<www.ville-ge.ch/musinfo/bd/cjb/africa/index.php>), as well as contributions from many individuals. For example, over 155 collaborators from 22 countries have supported Kew's World Checklist of Selected Plant Families (WCSP; <www.kew.org/wcsp>).

The Plant List provides a working list of known plant species that aims to be comprehensive in coverage at species level for all names of mosses and liverworts and their allies (bryophytes), and for all names of vascular plants, which include the flowering plants (angiosperms), conifers, cycads and their allies (gymnosperms), as well as the ferns and their allies, including horsetails and club mosses (ferns and lycophytes). For each name at the species level, information in The Plant List includes the describing author(s) of the name, the original place of publication, and an assessment of whether the name is accepted in current taxonomic use or is a synonym for another name. For each name included, wherever possible, links are also provided to an online database record, to its corresponding entry in IPNI, and to any further sources of information about that plant taxon. For each name record, The Plant List indicates the level of confidence that the status of the name record is correct; the confidence assessments are based primarily on the nature and taxonomic

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integrity of the source data. Currently, The Plant List recognizes ca. 298,900 accepted names (28.7% of the total) and 477,601 synonyms (45.9%). There are 263,925 names unresolved for taxonomic status, which constitutes 25.4% of all names in Version 1 of The Plant List. This latter category represents work in progress because there was insufficient information held in the component data sets contributing to The Plant List to determine whether these names should be accepted or considered as synonyms of other names. The Plant List is a working list, and future versions are planned to improve the quality and to reduce the number of unresolved names. There are opportunities to broaden the network of collaborators supporting The Plant List, which should thus help to reduce the number of unresolved names and to improve the quality of data. In future versions of The Plant List, it will be important to further broaden the scope of institutional and individual collaborations to help improve the quality and long-term maintenance of the data.

Global Strategy for Plant Conservation (GSPC) Perspective—Strengths and Weaknesses

From a GSPC perspective, The Plant List could be viewed as a success in several ways. It was the result of a global partnership, illustrating how a clearly agreed upon target can focus the activities of interested parties, helping them to achieve a common objective. The process in constructing The Plant List demonstrated the importance of GSPC cross-cutting issues, such as the development of tools and methodologies (Target 3), and of strengthening networks and collaboration for plant conservation at national, regional, and international levels (Target 16; CBD, 2010a). However, it is a significant lesson for the implementation of the GSPC, generally, that the partners involved already had their business aims closely aligned to the Target (Paton & Nic Lughadha, 2011). The production of taxonomic checklists has long been one of the principal activities of taxonomic institutions, and the vast majority of contributors were engaged in activities complimentary to Target 1 before it was set. Target 1 provided a focal point for collaboration rather than driving larger-scale business change within the institutions involved.

An important aspect of enabling institutional and individual collaboration was the ability to monitor progress toward Target 1. Measures such as the number and families of taxa covered in component global checklists enabled a gap analysis to be conducted. In 2005, this analysis enabled the Global Biodiversity Information Facility (GBIF) to target these gaps in a call for proposals that resulted in the funding of two of these taxonomic gaps, for the Compositae (<http://compositae.landcareresearch.co.nz/>) and Melastomataceae (<www.melastomataceae.net/>; GBIF, 2005).

Although Target 1 for the GSPC in 2010 can be viewed as a success from a global perspective, the need for stronger implementation at a national level has been noted (CBD, 2008; Paton & Nic Lughadha, 2011). Capacity building at national levels as identified in the Global Taxonomy Initiative (GTI; <http://www.cbd.int/gti/>) and covered under Target 15 of the GSPC (CBD, 2010a) is important to ensure that a working list or online flora can be maintained to ensure that it supports national-level support and implementation of the CBD. Different countries will have different priorities and require different foci of taxonomic research and service. Capacity building is likely to remain a priority in the next 10 years of GSPC implementation, but such capacity-building initiatives need to have clear goals to support implementation of the convention (Paton & Nic Lughadha, 2011).

National-level input is vital for the long-term compilation and maintenance of a global working list or online flora. For this paper, an analysis (Paton, unpubl.) of the distribution of species covered by Kew's WCSP underlying database, which covers 173 families and 123,000 species (WCSP, 2012), was carried out. The WCSP provides Taxonomic Database Working Group (TDWG) level 3 distributions (Brummitt, 2001) for the species covered. This level corresponds to countries or parts of large countries such as the United States or China. The analysis found that 58% of seed plant species are only found in one TDWG level 3 area and, therefore, endemic to one country (WCSP, 2012). Thus, for the majority of seed plants, a national treatment will also be a global treatment. Generally, within the GSPC, there needs to be a stronger interplay between global resources, such as The Plant List, and national level resources (CBD, 2010b). This interplay will facilitate long-term maintenance of global resources and will ensure that national level resources maintain up-to-date knowledge concerning more widely distributed species that may cross national boundaries.

The GSPC Target 1 set in 2002 (CBD, 2002) provided a vision that extends well beyond 2010. Going forward to 2020, The Plant List and any other system used to support the assembly of an online flora needs to consider its long-term maintenance. Currently, The Plant List (Version 1, 2010) can be regarded as only a single picture at any given time. It is not maintained as a dynamic online resource, although this is a possibility in the future. At the moment, corrections are fed back to the collaborating

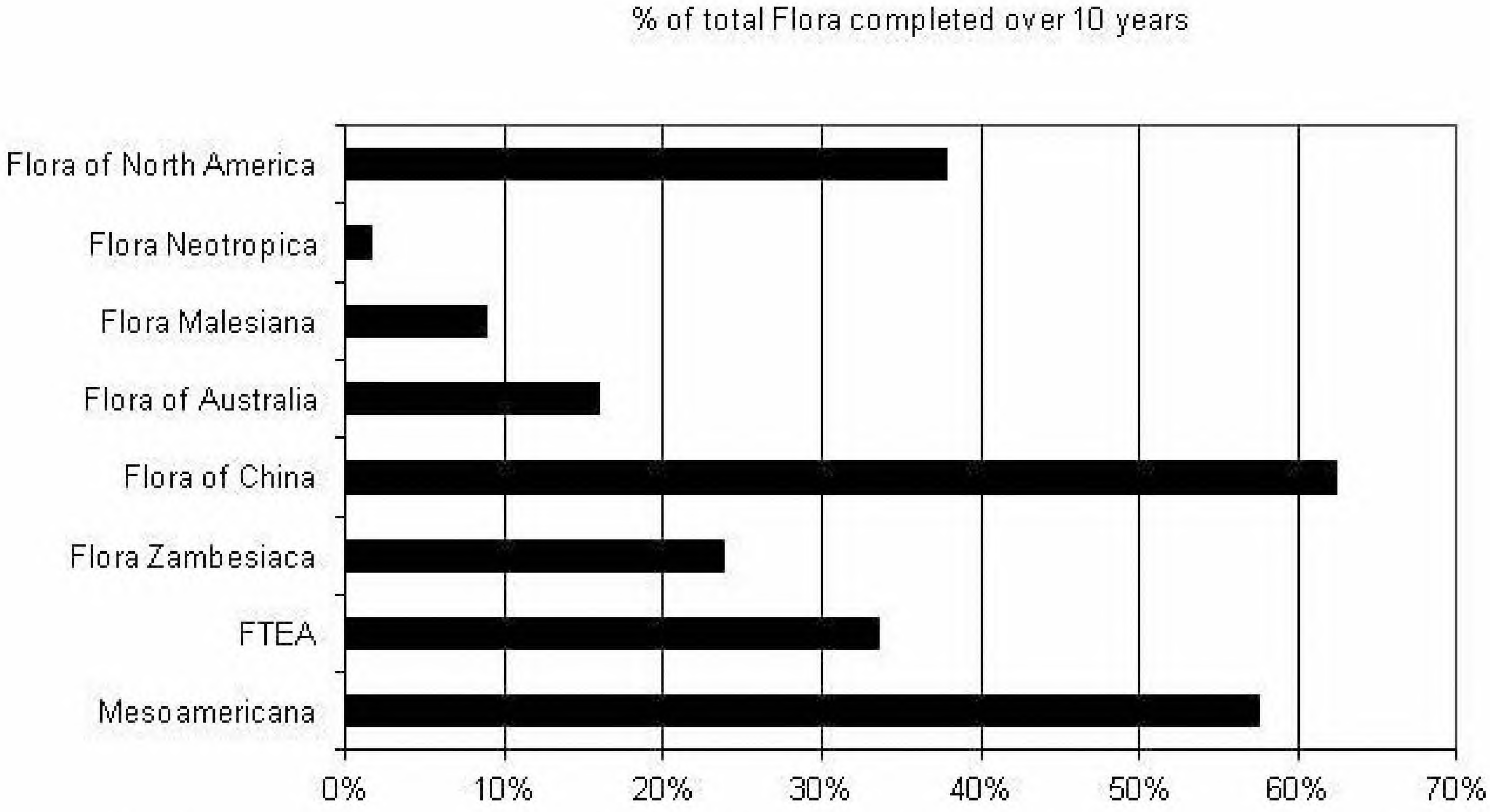

Figure 1. Progress in a selection of flora projects over the last 10 years. Totals from 2001 are taken from Heywood (2001). Results from 2012 come from the editors of regional or national flora projects asked to give totals for the number of species completed (see acknowledgments and Table 1 for details). Numbers reflect progress as of July 2012.

partner databases, and a planned new version of The Plant List will incorporate changes originating from these source databases. The lesson for GSPC implementation is that the processes used to achieve Target 1 on time may not be the most sustainable or efficient mechanisms to support implementation in the long term. Nevertheless, achieving the target of a working list for plant taxa worldwide is a vital first step toward an online flora.

THE 2020 TARGET 1: AN ONLINE FLORA OF ALL KNOWN PLANTS

It is important to clearly define what this online flora represents. This will enable potential partners to understand how best they can support work toward the current GSPC Target 1, and it will also facilitate monitoring and identification of gaps in implementation, which can then help further focus activities. For the 2010 Targets set by the COP Decision X/17 (CBD, 2010a), the definition of the first Target was initially provided by a rationale and description, which was then used as a basis for broader stakeholder consultation. Although the 2020 Target 1 has been agreed upon, with all 16 targets discussed at this workshop and the following liaison group meeting in St. Louis (CBD, 2011a), there is still opportunity for broader input from the scientific community who might implement the GSPC and policymakers. The aim here is to look at progress in large regional- or country-level floras to date in conjunction with lessons learned from the first 10 years of GSPC implementation and to identify factors that might assist implementation of Target 1 over the next 10 years.

Progress has been made in several large regional- or country-level floras over the last 10 years (Fig. 1; Table 1). Despite some impressive achievements, resulting in many species accounts being available for incorporation into an online global flora, none of these floristic projects were completed in a 10-year period. Nonetheless, the most impressive rates of progress were seen over the past decade for The Flora of China text series with 70% completion, Flora Mesoamericana with 57% completion, and the Flora of East Tropical Africa (FTEA) with around 34% of the known plant taxa treated. It is apparent that progress in larger regional areas, e.g., the Flora Malesiana and Flora Neotropica, tends to be slower than that in large country-driven projects such as Australia and China or in smaller regions such as the FTEA and Flora Mesoamericana; although, it should also be noted that monographs play an important role in covering plant groups from larger areas such as the Neotropics (Thomas, 1999). However, there is an important difference in the information content of traditional floras or monographs as contrasted with an online flora that meets Target 1 of the GSPC and supports the other 15 specific targets as well as the implementation of the CBD, generally. An online

Table 1. Progress in a selection of regional or national flora projects over the last 10 years. Totals from 2001 are taken from Heywood (2001). Results from 2012 come from editors of the flora projects asked to give totals for the number of species completed (see acknowledgments). Numbers reflect progress as of July 2012. In the New World, the Flora of North America treats plant taxa from the United States and Canada; the Flora Mesoamericana considers plants from Mexico south through Panama, and treatments in the Flora Neotropica extend to the south through Peru, Bolivia, and Uruguay. Plants of the African continent are investigated by the Flora of East Tropical Africa and the Flora Zambesiaca (Botswana, Malawi, Mozambique, Zambia, Zimbabwe, and the Caprivi Strip). The remaining projects treat plant taxa in China and Australasia, with the Flora Malesiana, which includes the following countries: Indonesia, Malaysia, Singapore, Brunei Darussalam, the Philippines, and Papua New Guinea in southeastern Asia.

	Species completed 2001	Species completed 2012	% Complete 2001	% Complete 2012	% Completed since 2001	Estimated total number of species
Flora Mesoamericana	3249	13,412	18%	76%	57%	17,683
Flora of Tropical East Africa (FTEA)	12,104	12,104	66%	100%	34%	12,104
Flora Zambesiaca	5960	8417	57%	80%	23%	10,528
Flora of China	9642	29,232	31%	93%	62%	31,360
Flora of Australia	6369	9452	33%	49%	16%	19,306
Flora Malesiana	8000	11,750	19%	28%	9%	42,500
Flora Neotropica	6237	7715	7%	9%	2%	90,000
Flora of North America	3249	11,004	16%	54%	38%	20,500

world flora that supports CBD implementation will need to present or link to broader information; otherwise, the Target will not support the implementation of the convention (Table 2). Given current rates of completion and requirement for additional information, clearly floristic writing as usual will not provide an online global flora that fully supports the implementation of the GSPC and the CBD by 2020.

Looking Ahead with Hindsight

The GSPC implementation has been reviewed at different times and from different perspectives. Such reviews include the Third National Reports of Parties to the CBD (<http://www.cbd.int/reports/analyzer.shtml>); an in-depth review of the implementation of the GSPC was considered by the Subsidiary Body on Scientific, Technical, and Technological Advice (SBSTTA) at their 12th meeting in Paris in June 2007 (CBD, 2007); and by the Conference of the Parties to the CBD at their ninth meeting (COP IX) in Bonn, Germany, May 2008, as reflected by the decisions arising there (CBD, 2008). This was followed by the CBD Plant Conservation Report issued by the Secretariat of the CBD (SCBD, 2009); and an online consultation and recent review of implementation in botanic gardens (Williams & Sharrock, 2010). The findings of these reviews were compared and contrasted by Paton and Nic Lughadha (2011). The factors found to be associated with successful implementation of the GSPC included: (1) the targets having a clear focus with identified outcomes and a degree of flexibility in how these outcomes were achieved; (2) a core group of stakeholders acting as a community and sharing similar business aims; and (3) a mechanism for monitoring progress and identifying gaps. How might these factors influence development of the online flora of all known plant species?

FOCUS AND FLEXIBILITY

As seen in Table 2, a flora traditionally covers a broad range of taxonomic, geographic, and nomenclatural information, yet an online flora that supports other targets of the GSPC (Targets 2, 7, 9–13; cf. Table 2) would cover an even broader range of information. One way to speed up the production of significant regional and country floras as well as The Plant List is to ask what is the minimum requirement for floristic treatments? This might be as simple as the provision of an accepted name of a taxon and its synonymous names to clarify what species exist and then what names have been used historically to recognize the taxon. As the CBD is implemented at a national level, it would be important to include, in a minimal view, country-level distributions so that country inventories could easily feed into and receive information from such an accepted plant name and distribution backbone. Such a minimal backbone for names of known plant taxa and their country-level geography would provide a clear focus for the GSPC Target 1, but also the flexibility to link and add further information to it. A similar approach was recently discussed at the 16th meeting of SBSTTA (CBD, 2012a). Existing descriptions, illustrations, and distributional detail could be linked to a taxon's record without the need for standardized text or

Table 2. Summary of the taxonomic information found commonly in traditional floras. This is contrasted with taxon information required to support implementation of other Targets (2, 7, 9–13)[1] of the Global Strategy for Plant Conservation beyond Target 1, which seeks "an online flora of all known plants" (Convention on Biological Diversity [CBD], 2010a).

Taxon information for traditional floras and Target 1	Additional taxon-level information supporting other targets
Accepted name	Conservation status (Target 2)
Synonyms	Genetic diversity (all Targets)
Description	Economic Use (Targets 11–13)
Identification key	Medicinal use (Targets 11–13)
Illustrations	Invasive potential (Target 10)
Distribution	Trade statistics, nondetriment information for CITES implementation (Target 11)
Relationships	Traditional uses (Targets 7, 9, 13)
Phylogeny	Common names (all Targets)
Literature citations	
Specimen and type citations	

[1] Additional Targets (CBD, 2010a). Target 2: An assessment of the conservation status of all known plant species, as far as possible, to guide conservation action. Target 7: At least 75 per cent of known threatened plant species conserved in situ. Target 9: Seventy per cent of the genetic diversity of crops, including their wild relatives and other socio-economically valuable plant species conserved, while respecting, preserving and maintaining associated indigenous and local knowledge. Target 10: Effective management plans in place to prevent new biological invasions and to manage important areas for plant diversity that are invaded. Target 11: No species of wild flora endangered by international trade. Target 12: All wild harvested plant-based products sourced sustainably. Target 13: Indigenous and local knowledge innovations and practices associated with plant resources maintained or increased, as appropriate, to support customary use, sustainable livelihoods, local food security and health care.

descriptive language as required by an established, traditional flora format. Other information integral to conservation, such as threat assessment, harvesting information, or a plant's invasive potential, could also be linked to such an initial backbone toward a global flora. An important element of any flora is a key to aid identification. However, keys to plant taxa do not need to operate at a global level. Existing country- or regional-level keys could be linked to a family and genus hierarchy. New and existing keys could be contributed to IdentifyLife (<www.identifylife.org>), thus benefiting from existing information and facilitating other key-building activities.

These elements could build directly on a backbone of scientific names for accepted, known plant taxa such as The Plant List, although a more sustainable system would have to be developed in order to keep the data and links up to date, and an inclusive system of editors would have to be developed to help maintain the system. Currently, The Plant List is static and cannot be edited online. There are successful examples of plant specialist communities maintaining data in online taxonomic systems, for example, the Solanaceae Source (<www.solanaceaesource.org>) and eMonocot (<http://e-monocot.org/>). Not every taxonomic group will have such a broad-based community to support its e-taxonomy, but more open, community-based collaborations will greatly facilitate taxonomic progress (Knapp, 2008) and achievement of the GSPC Target 1.

COMMUNITY SUPPORT: STAKEHOLDERS ACTING AS A COMMUNITY AND SHARING SIMILAR BUSINESS AIMS

The Plant List provides a names backbone, as discussed above, and includes detail from both regional datasets and global datasets. Monographic datasets that treat taxa globally have the advantage of providing a logically consistent view of the taxonomy for any area, whereas regional datasets may differ in their treatment of particular taxa, creating problems when these regional datasets are combined. It is likely that a flora of all known species would be composed of elements derived from both regional and monographic databases. Relatively few new data resources covering single large plant families have been developed over the last 10 years, the exceptions being the Compositae and Melastomataceae as previously mentioned. Ten large plant families that lack comprehensive or global species treatments or a database are shown in Table 3. Several of these larger families with significant taxonomic gaps have portions completed, e.g., in Apocynaceae, but global communities of plant specialists have not yet committed to the support necessary to maintain comprehensive databases for these families. This may be because the involved scientists have narrower taxonomic interests, as in the case of Apocynaceae where the subfamilies Apocynoideae and Rauvolfioideae have been reasonably, completely treated, but Asclepiadoideae, Periplocoideae, and Secamonoideae lag behind (WCSP, 2012). For other large families (cf. Table 3), funding or available specialists

Table 3. Families of vascular plants with over 2500 species that are not yet covered by a global species checklist.

Plant family	Estimated species number
Apocynaceae	4552
Malvaceae	4225
Ericaceae	3995
Apiaceae	3780
Acanthaceae	3500
Boraginaceae	2740
Urticaceae	2625
Ranunculaceae	2525
Amaranthaceae	2500
Lauraceae	2500

have not been available to complete treatments comprehensively across the family, e.g., Amaranthaceae. In other instances, taxonomists may be more interested in geographic or generic levels rather than family ones, as in Ericaceae. In both instances, energy necessary to pull the community together to produce this list has not been provided. Recent experience suggests that there are two means whereby global communities have been catalyzed to come together to produce a global checklist: (1) external funding as in the case of GBIF-funded projects (e.g., GBIF, 2005); and (2) draft electronic checklists being compiled from the literature and existing resources with expert communities then reviewing the list product, as in the case of those families covered by the WSCP (Paton et al., 2008; WSCP, 2012).

Regional- or national-level input into an online world flora will be important not only to fill the gaps among global species databases for particular families, but also to help maintain them and improve their quality. Broad participation will be vital for the long-term success of the GSPC. In terms of the GSPC Target 1 and the production of an online flora, those contributing to it must receive professional recognition for their efforts. The lack of accreditation for those compiling global checklists has been and still is a major barrier to completing a working list of known species (Paton et al., 2008). However, research councils are now considering such impacts as part of their research assessments. Projects such as the European Union–funded Virtual Biodiversity Research and Access Network for Taxonomy (ViBRANT; <http://vbrant.eu/>) focus on the development of virtual research communities involved in biodiversity science and must consider ways in which such online contributions can be recognized by the broader scientific community and funding sources. Objective measures of research impact and the value of contributions to an online flora will be easier to provide if the online flora connects to conservation and sustainable use information essential to those implementing the convention on the ground. Such linkages will boost the use and citations of the online flora and any associated data contributions.

MEASURING SUCCESS

As noted above, having a mechanism to monitor progress toward the target and to identify taxonomic gaps was an important factor in progress toward Target 1's working list prior to 2010. For the GSPC, such general monitoring of progress needs to be linked to the Aichi Biodiversity Targets (<www.cbd.int/sp/targets/>), both to demonstrate how the GSPC supports the strategic plan of the CBD and also to integrate monitoring and reporting with other environmental initiatives (CBD, 2011a). Otherwise, the report burden from different conservation or sustainable management initiatives constitutes a barrier to the acceptance and fulfillment of the targets (CBD, 2010a). The ways in which GSPC Targets support the Aichi Biodiversity Targets have been outlined by the Liaison Group on the GSPC (CBD, 2011a). The GSPC Target 1 is most relevant to the Aichi Biodiversity Target 19: "By 2020, knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, are improved, widely shared and transferred, and applied." Just as Target 1 underpins the other 15 GSPC Targets, it is also relevant to many of the other Aichi Biodiversity Targets, and a process is underway to develop indicators for the Aichi Biodiversity Targets. A set of headline indicators has been developed, under which operational indicators or metrics are then organized. The most relevant headline indicator to the GSPC Target 1 being "trends in accessibility of scientific/technical/traditional knowledge and its application" (CBD, 2011b). Underneath this, operational indicators apply at both global and subglobal levels, the most relevant to Target 1 address: (1) "trends in coverage of comprehensive policy-relevant sub-global assessments including related capacity building and knowledge transfer, plus trends in uptake into policy"; and (2) "number of maintained species inventories being used to implement the Convention." This second indicator reflects discussion within the Coordination Mechanism (CBD, 2011d) for the GTI concerning the need to have an indicator that reflected the importance of taxonomy underpinning the CBD and other environmental agreements (CBD, 2011c).

The Aichi Biodiversity Targets and their suggested indicators provide a mechanism for monitoring the implementation and impact of the environmental agreements such as the CBD, and to a less precise extent, to components programs such as the GSPC or GTI. However, to monitor progress and identify gaps in the implementation of the 16 GSPC Targets, more granular measures will be required. Such measures of progress for individual targets should be part of the GSPC tool kit (CBD, 2012b; <http://www.plants2020.net/>) to be developed to support implementation at both national and regional levels (CBD, 2010a). For Target 1, measures to help monitor progress will need to be developed. Such measures should cover:

(1) Taxonomic completeness. Unresolved scientific names should steadily decrease over time and, concomitantly, confidence should build in those names as peer-reviewed taxonomic decisions similarly increase. For example, in The Plant List, there should be a decrease in the number of unresolved names and an increase in the confidence ratings on the placement of names as accepted or synonyms over time.

(2) Links to additional information. As the online global flora develops, the numbers of accepted names with links to additional information necessary to implement the CBD should increase. Such additional information could include plant images, description, geographic distributions, and common names and coverage in taxonomic keys to aid identification. The number of linkages to support other targets of the GSPC could also be measured, e.g., an increasing number of conservation assessments, which would link to the GSPC Target 2, which notes "[a]n assessment of the conservation status of all known plants species, as far as possible, to guide conservation action."

(3) Support and participation. Measurable assessments toward progress of a global flora could be demonstrated by an increase in the number of countries supplying information to an online flora. Also pertinent would be the broadening distribution of contributing taxonomists and other committed individual scientists. As elsewhere in the scientific community, the number of citations of the online flora content would offer measureable progress toward widespread acceptance of the 2020 goal for the GSPC Target 1 toward the accomplishment of an online global flora.

CONCLUSION

If the online flora is to support GSPC implementation, then this Target 1 must also support conservation and sustainable-use projects at national and local levels, beyond providing or acting as a link to information concerning global plant diversity. To fulfill these functions, the online global flora should be complete and of sufficiently high quality such that information about plants can be found with confidence. Target 1 must link to information of use to those working in conservation and sustainable use at national and regional levels, and an online global flora must be supported by a broad range of stakeholders who can help to maintain and to update its taxonomic and other essential databases. Previous reviews have demonstrated that being able to monitor progress has assisted implementation of the GSPC Target 1 (Paton & Nic Lughadha, 2011), and it will be important to monitor progress using measures such as those detailed above.

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